

A national NWP-based thunderstorm and severe thunderstorm forecasting guidance system

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Introduction

The use of mesoscale numerical prediction output to complement the interpretation of conventional observations can add great value to the forecast process. The higher time and space resolution of the model data enables a forecaster to view the evolution of the weather situation in much greater detail and can provide an insightful framework within which to interpret the actual observations (eg. Mills, 2002).

With the growth of Australian knowledge of severe thunderstorms and the rapid improvements in accuracy of NWP through the 1990s it became possible to use meso-LAPS model guidance (Puri et al. 1998) to alert forecasters of environments that have the potential for severe convective weather. Knowledge about the environments favourable for the occurrence of Australian cool-season tornadoes (Hanstrum et al. 2002) provided the basis for the meso-LAPSs “coldies” guidance that became operationally available to forecasters through a web based display in early 2000. Also in 2000 the Colquhoun Decision Tree (CDT) was adapted to run operationally from the model (Mills and Colquhoun, 1998). It provided forecasting guidance for a broader range of storm types and severe convective weather.

While these automated guidance systems were a significant step forward their application in forecasting has been limited somewhat by the means of display of the output and, in some cases, by the ability of the forecaster to physically understand the decisions behind the guidance. When applying the CDT, with its many branches and techniques covering different storm types it can be difficult to diagnose the contributing factors behind the decisions sufficiently well to enable a forecaster to feel comfortable with the use of the techniques and in what circumstances to accept the guidance with confidence. In a study on how expert warning forecasters make decisions (Quoetene et al. 2003) emphasise the importance of providing forecasters with the tools to “...confirm, deny, or understand the validity of the output”, without which “...the experts had a tendency to distrust the tool, and in some cases not use it altogether.”

Despite the growth in knowledge of Australian thunderstorm environments, the increased use of NWP to identify particular storm environments, and a concerted attempt to enhance RFC staff training there are still regional differences in the application of the science to real-time forecasting.

In order to maximise the use of the forecasting guidance provided to forecasters and to progress and build on the advances made in understanding of the Australian thunderstorm science in the 1990s, a National project was commenced during 2003 to enhance the thunderstorm and severe thunderstorm guidance material available to RFCs from the Bureau’s meso-LAPS model. The initiative’s main aim was to support improved warning accuracy and timeliness for the Australian community and to State and local emergency services organizations, addressing the 2001 Strategic Assessment Recommendation 6 (Allen Consulting Group Pty Ltd and World Competitive Practices Pty Ltd, 2001) for the increase of the Bureau’s severe weather capability to meet community expectations. Central to the project aims was a process to review the best of the available science and extract from this a set of knowledge incorporating regional and seasonal differences within Australia. By

packaging a set of purpose built tools, and by providing forecasters with the means to conveniently access and display these, a more standardised approach to thunderstorm and severe thunderstorm forecasting should lead to a higher level of consistency in forecast policy both between individual forecasters and also between neighbouring RFCs. The project was designed to complement the Thunderstorm Interactive Forecast System (TIFS) project (Bally, 2003) that provides forecasters with radar-based tools for short term warning preparation and decision-making.

This paper describes progress on this work.

Background to the approach taken

The forecasting guidance system alerts forecasters to *environments* that have the *potential* to support thunderstorms and severe thunderstorms. In an operational setting this guidance can be used to focus the attention of forecasters onto observations in the threat areas to determine whether the signal in the model is also present in the real atmosphere. The evolution of the model fields in space and time should also provide a framework within which to view the observational data and thereby enhance its interpretation.

A National perspective has been taken, providing forecasting tools that can be used across the country, from the deep tropics through to mid-latitudes, all year round. Forecasters are provided with guidance on the likelihood of environments that can support thunderstorms driven by surface-based processes as well as mid-level processes, for which there has hitherto been no specific guidance. Tools are provided to look at tropical convection, particularly the identification of regions favourable to initiate tropical squall lines. Recognition and incorporation of cool-season differences has also been taken into account, with cool season decisions focussing on values of shear and instability in lower levels.

Due to the broad spectrum of shear and buoyancy regimes that can produce severe convective weather a classification system that focuses on severe *weather* type, rather than severe *storm* type was adopted (Fig. 1). Environments for tropical squall lines and supercells are identified separately since these storm types, once initiated, can be very long-lived producing damage over large areas. If the conditions for supercell thunderstorms are met then the full array of severe weather phenomena may be experienced.

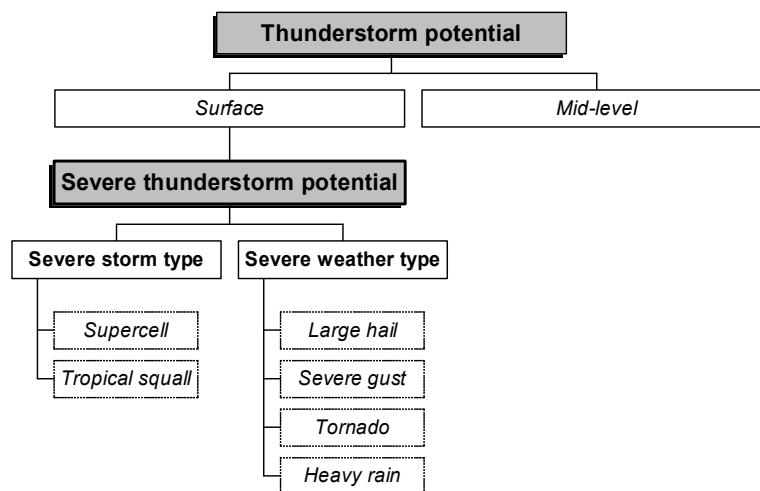


Fig. 1: The thunderstorm and severe weather classification system used.

The approach taken was to define a set of physically based diagnostic fields, together with critical thresholds of these. An *ingredients* based approach rather than a *synoptic pattern* based approach was used since this has the advantage of alerting forecasters to situations in which the ingredients favourable for severe convection may come together through an unusual combination of synoptic circumstances. A summary of the key ingredients used in the decisions to forecast the threat areas of severe weather/storm threat are given in Table 1.

Table 1: Physical basis for the selection of ingredients used in *storm* type and *severe weather* type decisions together with some key references.

Storm type	Ingredients
Thunderstorm (surface)	Buoyancy at 500 hPa (700 hPa) for warm season (cool season), low-level up-motion, a relatively small amount of convective inhibition (CIN) and the requirement that an updraft reaches -20°C or colder, in order that electrification can occur.
Thunderstorm (mid-level)	As for surface based decisions except check for up-motion and instability above the surface up to 500 hPa. <i>Conroy and Hanstrum (2002)</i>
Supercell	Strong instability combined with strong values of shear in the lowest 3-4 km AGL (warm-season) or in the lowest 1.5-3 km AGL (cool-season). <i>Dickins (1994), Treloar and Hanstrum (2001)</i> .
Tropical squall line	Modest instability, moderate shear in low to mid-levels and a block of steady unidirectional winds in the low to mid-levels. <i>Gill and Kersemakers (1993)</i>
Severe weather type	Ingredients
Large hail	Strong updraft (both a function of the buoyant energy and the storm-relative inflow) up to the region of maximum hail growth around -20°C , combined with a relatively low freezing level in the environment. <i>Nelson (1983)</i>
Heavy rain	Warm, deep, moist layer with moderate deep, instability layer with either slow moving <i>storms</i> or a slow moving <i>system</i> focussing up-motion over the same area for a number of hours. <i>Doswell et al. (1996)</i>
Tornado	Sufficient instability in low levels combined with strong shear in the lowest kilometre of the atmosphere. <i>Craven et al. (2002), Hanstrum et al. (2002)</i>
Severe convective gust	Strong updraft combined with large values of the Downdraft Maximum Available Potential Energy or alternatively, strong mid-level winds combined with more modest instability. <i>Taylor and Webb (2002), McCready and Hanstrum (1996)</i>

The use of two levels of alerts for most of the forecasting decisions allows forecasters to see whenever a set of ‘favourable’ or ‘very favourable’ conditions are met and compensates to some extent for the disadvantages associated with use of fixed thresholds. Also, the provision of the meso-viewer (see ‘display tools’ section below) enables a forecaster to view the individual components of the fields and see where thresholds in the ingredients may be close to being reached. Future versions of this work may well move towards the approach taken by Mills (2003) where probability distributions of the likelihood of observed thresholds being met in the model are provided as forecasting guidance.

Display tools

The system provides forecasters with tools to easily view and display the composite threat fields and the individual ingredients that combine to produce these. The data viewing tools provided enhance the ability for forecasters to view the component ingredients behind the decisions, and will hopefully enable them to develop greater level of trust and confidence in the guidance.

The material is provided to RFCs in several ways. A purpose built website has been designed, see: <http://gale.ho.bom.gov.au/cgi-bin/bm/wefor/cme/severewx/thunder.pl.dev> The site features a National map on its front-page colour highlighted to show areas where there is potential for thunderstorms/severe convective weather and supercells to occur, with

the ability to zoom in on geographical regions. Model forecast output is partitioned into information for 'today' and 'tomorrow', the forecast periods that are typically used in providing information to the public. The second page of the site allows the forecaster to view the storm/severe convective weather types that are forecast and the third page displays a time series of the field selected.

The site links to the SHear and Instability in Real-Time (SHIRT) site that shows, for each region, the observed values of surface Lifted Index and shear based on the current surface conditions and the most recent upper air temperature and wind soundings. It colour highlights levels when shear and instability thresholds for tornadoes and supercells are met.

Links are also provided to on-line training (see below), other forms of National observational data (radar, enhanced IR satellite imagery, aerological soundings, hodo-tool), current warnings, climatology of thunderstorms and lightning, and regional verification.

Forecasters will be able to launch the proto-type meso-viewer for each region from the site. The meso-viewer enables the forecaster to easily display and overlay model fields, so that more detailed diagnosis of the model output can be carried out. See:

http://gale.ho.bom.gov.au/bm/internal/wefor/projects/thunder/mesoviewer/cases/CAS_E08_0101623.html

The meso-viewer graphical user interface leads forecasters through a forecast process closely aligned to previously identified core competencies for thunderstorm forecasting (Deslandes, this volume). It is customised to display 3-hourly meso-LAPS fields in each region and the GUI is designed so that fields are arranged according to the forecast process. Another tool to assist with forecast process will be the ability to overlay the current objective analysis of surface observations on the model forecast for that element at the time, enabling forecasters to reality check the model. In time, the data viewer will be replaced by the AIF2 Forecast Data Viewer (FDV) and should allow development of the FDV to be more focussed. The information will also be provided to forecasters through TIFS.

Training

The training aspects of this project are integral to its objectives and are discussed in more detail in Deslandes (this volume). Regional Office staff visited BMTC in early July and prepared web-based case studies of Australian severe storm types including the ability to access the meso-LAPS diagnostic fields through the meso-viewer. Examples of these cases can be seen at :

http://bmtc.ho.bom.gov.au/roger/html/ts_wkshop/intro/index.htm

The method used to disseminate the knowledge to RFCs has been the train-the-trainer model. Regional trainers attended a 1-day training session in BMTC in early September and training to all RFC staff is being carried out around the country in September and October 2003. The National website has a link to purpose built training material that includes a section on the rationale behind the physical ingredients and thresholds used in the decisions, links to the case studies and links to the PowerPoint talk that formed the basis for regional training.

Verification

Verification during the first season of operation will be carried out both within RFCs and within BMRC. A copy of the RFC verification form can be seen at: <http://serva.qld.bom.gov.au/~matthews/tsnwp/menu.htm>. Workload permitting, the RFCs will carry out a daily verification of the guidance at capital cities and other key locations. Within BMRC there will be objective verification performed for some key model forecast parameters at selected radiosonde sites.

Future directions

The system described will be operational and supported within NMOC by November 2003. It is a prototype system, largely untested in a real-time setting. The thresholds used in the forecast decisions have not been tuned to model biases of the forecast ingredients (apart from the coldies guidance) and the techniques, while based on sound physical principles will inevitably benefit from further tuning. The verification procedures, both those done subjectively in RFCs, and the objective model verification in BMRC, will provide useful measures of the effectiveness of the guidance and how it may be refined for future use. A meeting has been scheduled in late May 2004 in which a complete review of the forecasting system performance during the 2003/2004 warm-season will be carried out. Refinements based on the summer experience will be undertaken during the winter of 2004.

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